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# HIDDEN COSTS OF THE GREAT LONDON SMOG: EVIDENCE FROM MISSING BIRTHS

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## Abstract

This article measures the effect of the Great London Smog on fetal loss by testing for missing births in the subsequent nine months, using newly available data. Results show the five day smog resulted in a 3% reduction in the size of the cohort affected in the third trimester, and a 1.5% reduction in the size of the cohort affected in their first trimester.

## 1 Introduction

Over 12,000 people lost their lives prematurely after exposure to the Great London Smog of 1952 (Bell *et al*, 2004). This paper tests whether the five-day Smog also caused mortality among those who were *in utero* at the time. To my knowledge, this is the first paper studying a possible link between fetal loss and exposure to a short urban smog<sup>1</sup>.

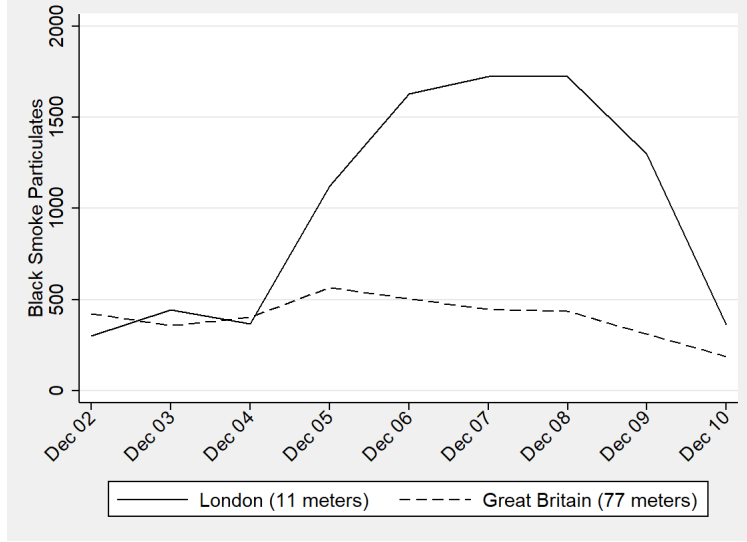
For long-term pollution exposures over the pregnancy, there is good evidence in health economics that a number of proxies for fetal health are affected, including birthweight, prematurity, and neonatal mortality (Currie *et al*, 2014). Within epidemiology, Siddika *et al* (2016) perform a meta-analysis of 13 studies of pollution and stillbirths, finding a suggestive link between the two. There is much less evidence about fetal loss and short exposures to pollution, such as found in urban smogs. An exception is Periera *et al* (1998), who use two years of daily data on late fetal loss (after 28 weeks) from Sao Paolo, linked to daily data on five pollutants. They find a significant association between births and a summary measure of the pollution, up to a lag of five days.

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<sup>1</sup>The review below relates to evidence about fetal loss. However, for recent studies of the effects of London's Smogs on mortality among adults and infants, see Clay and Troesken (2011), Beach and Hanlon (2018), and Hanlon (2018).

Figure 1: Black Smoke Particulates ( $\mu g/m^3$ ) in London and Great Britain during the 1952 Smog. Data from the Fuel Research Board.



The estimates above are likely to be lower-bounds as fetal loss is only ordinarily recorded in later pregnancy, after around twenty weeks. Jayachandran (2008) circumvents this, and other data challenges, by observing ‘missing births’ in the 2000 Indonesian census following a large wildfire, finding a 1.2% reduction in the size of the affected cohort. Sanders and Stoecker (2015) take another approach, measuring the effects of the 1970 Clear Air Act on birth ratios, finding that a standard deviation increase in TSP particulates reduced the percentage of male live births by 3.1%.

## 2 Background and Data

The Great London Smog began on the 5th of December 1952 and lasted five days. During these days, average Black Smoke particulates was  $1500 \mu g/m^3$ , with a peak daily average of  $1720 \mu g/m^3$  on the 8th of December. The Smog was caused by an atmospheric temperature inversion that prevented the normal dispersion of pollution. As shown in Figure 1, other areas of the U.K. were not affected.

Following Jayachandran (2008), this paper tests for ‘missing births’ in London in the nine months following the Great London Smog. Information on quarterly births from 1948-1965 in London and England & Wales comes from the records of the Registrar General for Births, Deaths, and Marriages and can be seen in Figure 2. This is the official record of births for the United Kingdom, and should contain the universe of registered births<sup>2</sup>. Data

<sup>2</sup>Registration of births has been compulsory in the U.K. since the Births and Deaths

Table 1: **Summary Statistics:** Birth data from the Registrar General, Weather data from the MET Office, Pollution data from the Fuel Research Board.

VARIABLES	(1) mean	(2) sd	(3) min	(4) max
Quarterly Births, London	16,012	1,534	13,462	19,103
Quarterly Births, England and Wales	154,814	15,451	127,288	187,674
Quarterly Minimum Temperature	0.318	1.891	-3.600	4.300
Quarterly Average Black Smoke	150.8	33.36	100.6	218.7

on weather conditions comes from the U.K. Meteorological Office. Data on black smoke particulates comes from the official publications of the Fuel Research Board<sup>3</sup>. The series for London spans from 1950-1958 and is based on data from fifteen meters. Summary statistics for the main variables can be seen in Table 1.

### 3 Statistical model and estimation

The aim of the statistical model is to compare actual births in 1953 - when children affected *in utero* would be born - to a counterfactual capturing expected births in the absence of the Smog. The dependent variable is log births ( $BIRTHS_{ts}^L$ ) in quarter  $t$  and season  $s$ . The overall trend of log births between 1948 and 1965 is captured with a polynomial  $\phi(\tau)$  of degree  $\tau$ , and three seasonal dummies  $D_s$ . Log births in the rest of England and Wales ( $BIRTHS_{ts}^E$ ) - which was unaffected by the Smog - are included to capture deviations from this trend due to unobserved economic, environmental, or other nation-wide factors. Additional data relating to environmental exposures is available from 1950-1958, and are included for some specifications as  $E_t$ . This contains the average pollution exposures and minimum temperatures during the nine months prior to the quarter of birth. Lastly, the model contains dummies for quarters following Smog events  $D_t^{Smog}$ . The coefficients of interest are  $\gamma$ , the difference in log births in London following the Smog, relative to the modelled counterfactual.

$$BIRTHS_{ts}^L = \alpha + \beta_1\phi(\tau) + \beta_2D_s + \beta_3BIRTHS_{ts}^E + \beta_4E_t + \gamma D_t^{Smog} + \epsilon_{ts} \quad (1)$$

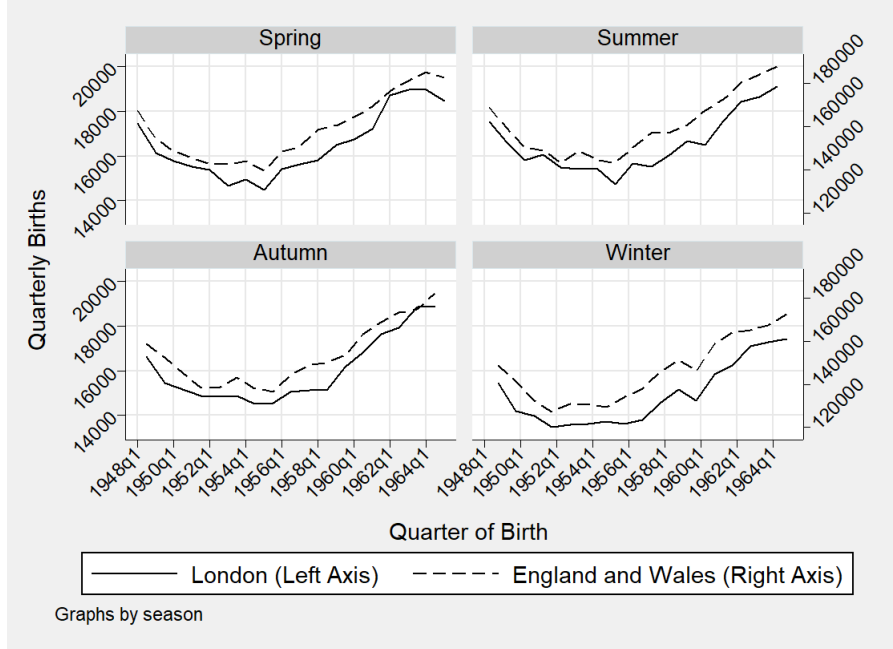
Estimation of the model is by ordinary least squares, with robust standard errors. Results will be shown for different lag-lengths for the polynomial

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Act of 1874.

<sup>3</sup>Available in the UK National Archives. Conversion of BS to a gravimetric measures such as TSP is not precise. In the context of the Great London Smog, Bell *et al* (2004) use a 1:1 conversion.

Figure 2: Quarterly Births in London and England and Wales, by season. Data from the Registrar General.



$\phi(\tau)$ , and a preferred specification will be chosen using the reported AIC and BIC.

## 4 Results

Estimated coefficients from Equation 1 can be seen in Table 2. Columns (A1)-(A5) are from the complete series of birth data from 1948-1965. The AIC and BIC both suggest adjusting for long-run trends with a fifth order polynomial, seen in the top half of Figure 3. Discussion will focus on this specification (A5). Much of the variation in the London birth series was shared with the England and Wales series, and the associated coefficient is highly significant in all specifications. This relationship also captured most of the seasonality in the data. Of the seasonal controls, only the winter dummy was significant, indicating that although births are lowest in the Winter in England and Wales, they are 0.4% more so in London.

The dummy for Winter 1952 in (A5) includes the period of the Smog, and shows 1.2% fewer births, though significant at only the 10% level. The dummy for Spring 1953 captures those affected by the Smog while in the third trimester, and indicates a 3.4% drop in births, significant at the 1% level. The dummy for Summer 1953 captures those affected in the second trimester, and shows a 1.1% drop, though the estimate is not statistically sig-

nificant. The dummy for Autumn 1953 captures those in the first trimester during the Smog; the coefficient suggests a 1.6% drop in births, significant at the 5% level. The dummy for Winter 1953 captures those who were conceived too late to be affected by the Smog. The coefficient is negative but not significantly different from zero. For this longer series, two additional dummies were included for the three quarters following the 1948 and 1962 Smogs. The estimated coefficients showed a 4% decline in births against expectations in the three quarters following the 1948 Smog, significant at the 5% level, but no change after the (less severe) 1963 smog.

Columns (B1)-(B4)<sup>4</sup> were estimated on data from 1950-1958, and include additional controls for average levels of pollution exposure and minimum temperatures in the three quarters prior (the period during which a child would be in utero.) The length of polynomial lag suggested by AIC and BIC is sensitive to the number of impact dummies included, but is always (B1) or (B3). With the five impact dummies, (B1) is selected, and discussion will focus on this specification. In terms of results, much of the discussion above holds. The added controls for temperatures and particulates had estimated coefficients with the expected (negative) sign but very small magnitudes that were not statistically significant. This is most likely because the fitted line, the seasonal dummies, and the idiosyncratic shocks picked up by the England and Wales series had already picked up much of the variation in births due to environmental causes. The estimated impacts in (B1) were similar to those in (A5), except that the negative impact on those in the second trimester was significant at the 5% level.

## 5 Discussion

Overall, results suggest that the five day smog had a significant effect on fetal loss, especially for those affected in the first and third trimesters. The Great London Smog was particularly severe with a peak daily average of roughly  $1,700 \mu\text{g}/\text{m}^3$  TSP. A natural question is whether similar events happen in modern times. Comparisons require converting Smog measures from Black Smoke to TSP, and then to PM2.5, which will inevitably introduce error. Following Cao *et al* (2011) and converting to PM2.5 at a ratio of around (1:3) would give a peak daily average of around  $570 \mu\text{g}/\text{m}^3$  PM2.5 during the Great London Smog. In 2017, Delhi experienced a week-long Smog in early November in which levels of PM2.5 particulates remained at  $600 \mu\text{g}/\text{m}^3$  for sustained periods<sup>5</sup>. In 2013, much of North East China was covered by an

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<sup>4</sup>The fifth order polynomial term in what would be specification (B5) was omitted due to collinearity.

<sup>5</sup>Hindustan Times, 11th November 2017, "Air clean-up act: PM10 out of emergency levels, PM2.5 to follow soon" Available at: <http://www.hindustantimes.com/delhi-news/air-clean-up-act-pm10-level-out-of-emergency-levels-pm2-5-to-follow-soon/story-uygP86Y7UKhisYI8teiUIL.html>

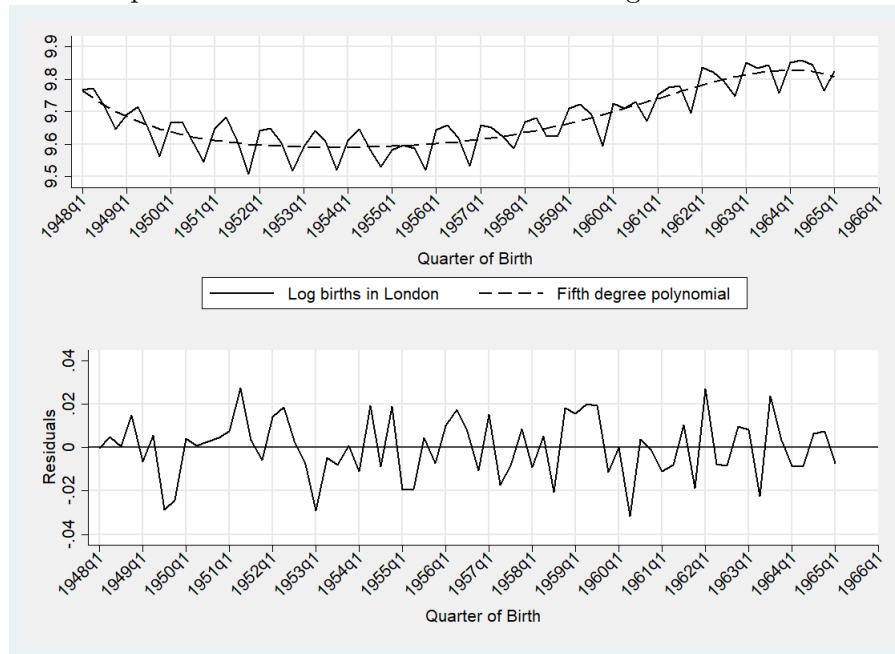
Table 2: **Estimated coefficients from Equation 1:** Log quarterly births in London regressed on a polynomial trend, seasonal dummies, and dummies for quarters following the 1952 Smog. Regressions reported in columns A1-5 include data form 1948-1965, AIC and BIC select column A5. Columns B1-4 include environmental and pollution controls, and include data from 1950-1958, AIC and BIC select column B1. Birth data from the Registrar General, Weather data from the MET Office, Pollution data from the Fuel Research Board.

VARIABLES	(1) (A1)	(2) (A2)	(3) (A3)	(4) (A4)	(5) (A5*)	(6) (B1*)	(7) (B2)	(8) (B3)	(9) (B4)
1952, Winter (Smog)	0.003 (0.007)	-0.002 (0.006)	-0.001 (0.006)	-0.005 (0.006)	-0.011* (0.006)	-0.011 (0.007)	-0.012 (0.008)	-0.017* (0.008)	-0.016 (0.010)
1953, Spring (T3)	-0.022*** (0.005)	-0.025*** (0.005)	-0.024*** (0.006)	-0.028*** (0.005)	-0.035*** (0.006)	-0.030*** (0.006)	-0.031*** (0.007)	-0.035*** (0.008)	-0.034*** (0.009)
1953, Summer (T2)	-0.007 (0.007)	-0.004 (0.006)	-0.002 (0.010)	-0.004 (0.009)	-0.011 (0.009)	-0.016** (0.007)	-0.018* (0.010)	-0.022* (0.011)	-0.019 (0.015)
1953, Autumn (T1)	-0.015*** (0.005)	-0.009* (0.005)	-0.006 (0.009)	-0.008 (0.008)	-0.015* (0.008)	-0.014*** (0.004)	-0.017 (0.010)	-0.020* (0.011)	-0.016 (0.016)
1953, Winter	0.010 (0.007)	0.006 (0.005)	0.007 (0.006)	0.008 (0.006)	-0.002 (0.006)	0.000 (0.007)	-0.001 (0.009)	-0.003 (0.009)	0.001 (0.015)
L(births), Eng+Wales	0.947*** (0.033)	0.685*** (0.076)	0.641*** (0.151)	0.654*** (0.141)	0.657*** (0.144)	0.749*** (0.159)	0.785*** (0.199)	0.829*** (0.219)	0.810*** (0.235)
season = 2, Summer	-0.005 (0.007)	-0.000 (0.007)	0.000 (0.007)	-0.001 (0.006)	-0.001 (0.006)	0.005 (0.008)	0.005 (0.009)	0.003 (0.008)	0.004 (0.009)
season = 3, Autumn	0.005 (0.007)	-0.002 (0.007)	-0.004 (0.007)	-0.004 (0.006)	-0.004 (0.006)	-0.000 (0.011)	0.001 (0.012)	0.002 (0.012)	0.001 (0.013)
season = 4, Winter	-0.021*** (0.008)	-0.041*** (0.009)	-0.045*** (0.014)	-0.046*** (0.013)	-0.045*** (0.013)	-0.033* (0.018)	-0.030 (0.022)	-0.026 (0.022)	-0.028 (0.025)
Ave Pollution, in utero						-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Min Temp, in utero						-0.001 (0.002)	-0.000 (0.002)	-0.001 (0.002)	-0.001 (0.002)
Observations	68	68	68	68	68	34	34	34	34
R-squared	0.964	0.973	0.973	0.977	0.981	0.957	0.957	0.960	0.960
AIC	-338	-354	-354	-362	-369	-194	-193	-193	-191
BIC	-320	-332	-332	-335	-338	-181	-177	-176	-173
Deg. of Polynomial Trend	1	2	3	4	5	1	2	3	4
Environmental Controls	no	no	no	no	no	yes	yes	yes	yes

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Figure 3: Expected Quarterly Births in London: The upper figure shows the log births data fitted with the fifth degree polynomial chosen by the AIC and BIC. The lower figure shows the residuals from Equation 1, excluding the 1953 impact dummies. Birth data from the Registrar General.





apparently much more severe smog, with levels in Harbin reaching over 1000  $\mu\text{g}/\text{m}^3$  PM2.5<sup>6</sup>.

## 6 Conclusion

This paper estimated the effect of the Great London Smog on fetal loss by testing for ‘missing’ births in the subsequent nine months. Results show around a 3% reduction in births among the cohort affected by the Smog in their third trimester, and a 1.5% reduction in births among those affected in their first trimester. Most specifications also showed a 1.4% reduction in births among those affected in the second trimester, though this result was statistically significant in only some models. Overall, it appears that the five days of the Great London Smog had a significant effect on fetal mortality. To my knowledge, this is the first direct evidence that a short urban smog can cause fetal loss. The Great London Smog was particularly severe, but there is evidence that events of similar magnitudes have occurred in India and China recently. It is for future research to determine whether these recent events had similar effects for fetal loss.

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<sup>6</sup>Guardian, 24th August 2013, “China hit by another airpocalypse as air pollution cancer link confirmed” available at: <https://www.theguardian.com/environment/chinas-choice/2013/oct/24/china-airpocalypse-harbin-air-pollution-cancer>

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